A Comparative and Analytical Study of the Industrial Technique of Selected Wrappings Linen from the Late Period (26th Dynasty) (664-525 B.C.)

Assist.Prof. Dr. Ibrahem Mohammed Mohammed Badr

Associate Professor Conservation Department. Faculty of Archaeology and Tourism Guidance. MUST UNIV, 6th October City, Egypt.

ibrahembadr77@gmail.com

Dr. Ibrahim H. M. Ibrahim

Lecturer High Institute of Tourism, Hotel Management and Restoration, Abu Qir, Alexandria. Egypt.

ibrahim_elkholy88@yahoo.com

Abstract:

The Saqqara archaeological site in Giza is one of the most important archaeological sites in the world, not only in Egypt, due to the historical and archaeological significance of its temples and tombs. Misr University for Science and Technology, Faculty of Archaeology and Tourism Guidance, has been working with the Supreme Council of Antiquities at the eastern Tabih Aljaysh site in Saqqara since 2020.

The mission has discovered many burial shafts dating back to the late period, in which dilapidated wooden coffins and sarcophagi were found, containing human bones covered with worn-out linen fabric wrappings and shrouds. It was found that the mummification process during that time period focused on the external appearance of the deceased, such as the colors of the coffins, without paying attention to the quality of the wood used. Similarly, the linen fabric wrappings and shrouds were in good external shape, but they were made of weak types of linen.

This was evident through the research, which examined four different samples of human skeletal remains and found good results in terms of industrial technique, shape, and technical evaluation, but weakness in terms of chemical composition due to the chemical reaction between the materials used in mummification and the linen wrappings and shrouds. The research utilized scanning electron microscope with EDAX, and gas chromatography–mass spectrometry analysis to evaluate the quality of industrial and technical evaluation of linen wrappings and shrouds.

This scientific paper highlights an important stage in the development of the linen industry throughout ancient Egyptian times and shows the extent of the development of the ancient Egyptian industries in the production of fine linen fabric using the mordant of alum and safflower dye to decorate the linen fabric.

Keywords:

Mummy, Late Period, Resins, Wrappings, Shrouds, Shroud Techniques, Scanning Electron Microscope Saqqara, Gas chromatography–mass spectrometry

Doi: 10.21608/mjaf.2023.206777.3086

الملخص:

يعد موقع سقارة الأثرى من أهم المواقع الأثرية بالعالم بما يحويه من مقابر ومعابد، حيث عملت بعثة كلية الآثار والإرشاد السياحى جامعة مصر للعلوم والتكنولوجيا تحت إشراف وزارة الآثار بموقع تبة الجيش موسم ٢٠٢٠م. قامت البعثة بالكشف عن العديد من الدفنات التى ترجع إلى العصر المتأخر، والتى عثر من خلالها على بقايا بشرية تم تكفينها بلفائف كتانية حالتها مهترئة. تقوم الدراسة على أساس عمل دراسة مقارنة لتكنيك صناعة أربعة من الأكفان الكتانية من خلال الفحص البصري والفحص الميكروسكوبى باستخدام الميكروسكوب الإلكترونى الماسح المزود بوحد التحليل العنصرى، كذلك تمت الاستعانة بالتحليل الكروماتوجرافى الغازى المزود بمطياف الكتلة لتحديد نوع الصبغة الحمراء المستخدمة لصباغة أحد الأكفان موضع الدراسة. وقد أتضح من خلال الدراسة أن كافة الأكفان تم نسجها باستخدام خيوط كتانية بتركيب نسجى سادة ١/١، حيث تميزت خيوط السداء بالغزل المزوى لكي تتحمل الإجهادات الواقعة عليها أثناء النسج بينما خيوط اللحمة غير مزوية بما يؤكد الفهم والإدراك الكبير للنساج المصرى القديم فى هذه الحقبة لميكانيكية حركة النول والاجهادات الواقعة على خيوط السداء دون اللحمة. وقد تميزت كلا من خيوط السداء واللحمة بأنها برمت جهة اليسار على هيئة حرف "S" كسمة مميزة لأغلب المنسوجات المصرية القديمة. هذا وقد ثبت من خلال التحليل الكروماتوجرافى الغازى المزود بمطياف الكتلة أن الصبغة الحمراء هى صبغة العصفر، حيث تم إجراء تحليل عنصرى للمرسخ المستخدم مع الصبغة وتبين تواجد عنصر الحديد.

الكلمات الدالة:

مومياء – العصر المتأخر – الراتنجات – اللفائف الكتانية – تكنيك الأكفان – الميكروسكوب الإلكترونى الماسح - التحليل الكروماتوجرافى الغازى المزود بمطياف الكتلة.

1. Introduction:

The Tabih Aljaysh site, located in Saqqara (Fig. 1), is considered one of the most significant archaeological sites. Despite its importance, there have been few scientific activities at the site due to its preserved state (1). Numerous burial shafts from the late period have been discovered at the site. (Fig. 2). A number of objects have been uncovered, including groups of wooden coffins and stone sarcophagi, showing that the location dates back to the late era (2).

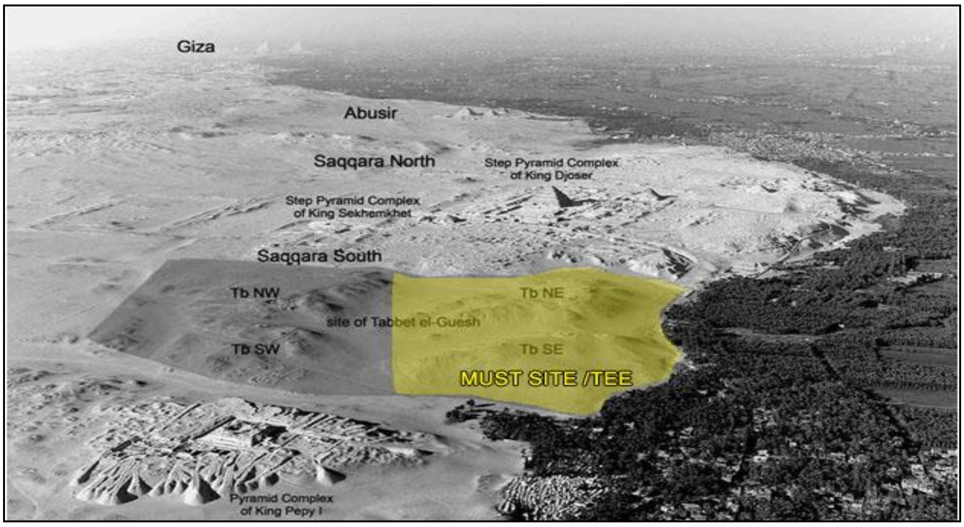


Fig. 1 points at the excavation site of Misr University for Science and Technology and the Supreme Council of Antiquities, where samples of linen wrappings were obtained during the 2021 excavation mission season.

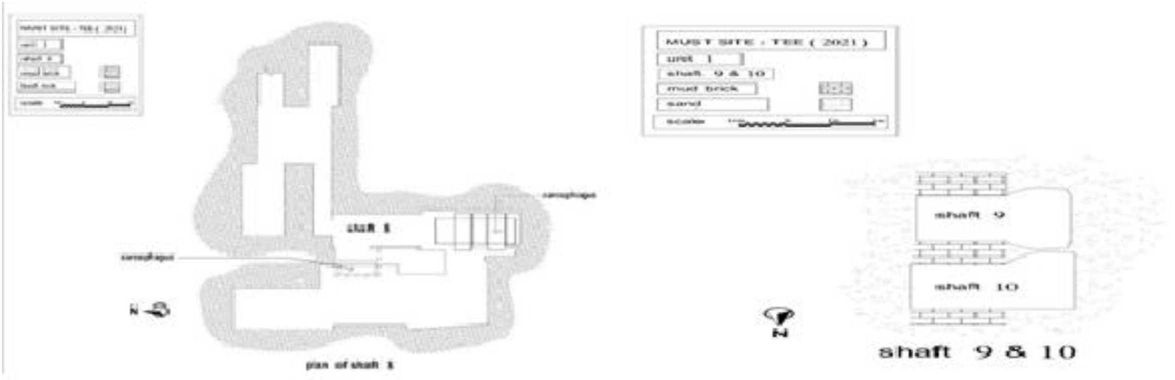


Fig. 2 point to shafts 8, 9 and 10, which were discovered during the excavation mission. Human remains with remnants of linen fabric wrappings were found inside.

Pottery from the archaeological site has also been used to help date it to the late period. Linen manufacture was an important aspect of ancient Egyptian industry and economy. The flax plant, which was used to produce linen, grew along the Nile River's banks, where the soil was rich and productive (3). There were various steps involved in producing linen. First, the flax plants were harvested, and then the retting procedure was used to separate the fibers from the stalks. The stalks were submerged in water for many days to retting, so that the fibers would become loose and be simple to extract (4).

Following retting, the fibers were thrashed to eliminate any remaining plant matter before being combed to distinguish between long and short fibers. The long fibers were spun into thread on a spindle, and then they were woven onto a loom to create fabric (5).

Linen manufacture was a labor-intensive operation requiring expert personnel. Women were often in charge of spinning and weaving the fabric, while men labored in the flax fields (6). Ancient Egypt employed linen for a variety of things. Given that it was cool and pleasant in the warm climate; it was the most often used fabric for clothes. People of all socioeconomic classes wore linen clothing, although the quality and style of the garments varied based on the wearer's social standing (7).

Linen was also used to make household items such as sheets, towels, and curtains. These items were often decorated with intricate designs and patterns.

The use of linen was not limited to everyday life; it was also an essential material for mummification. The linen wrappings used for mummification were soaked in resin to ensure that the linen would not unravel and to protect the body from insects and decay.

An essential component of ancient Egypt's industry and economy was the production of linen. Although linen was widely used in daily life, producing it was a labor-intensive process that required experienced artisans (8). Ancient Egyptian burial customs included the use of linen wrappings, which was a major aspect of the linen industry's contribution to mummification (9).

1.1 Linen fabric wrapping in mummifications technique in ancient Egypt.

The late period in ancient Egypt's mummification procedure focused on the mummy's exterior coverings before treating the body interior. Before removing the internal organs, which were stored in Canopic jars, the body was cleansed and purified (10). Natron was then placed on top of the body to dry out the tissues and stop decomposition. The natron was eventually taken off, and the corpse was bandaged with linen (11).

The Late Period: Compared to earlier times, this period's mummification method was less sophisticated. The linen wrappings, their application technique, and their ultimate shape on the mummy's body were of great interest to embalmers when it came to the mummy's outward appearance (12).

The analysis and registration procedures of the obtained samples revealed that the linen wrappings were technically of a distinctive style (13).

While mummification was practiced at this time, the quality of the linen used to wrap the mummies varied greatly, with some being wrapped in fine linen and others in rougher, lower-quality linen. Furthermore, bitumen was frequently used at this time as a preservative, which frequently caused the linen bandages to degrade over time (14). The analysis and registration procedures of the obtained samples reveal that the linen rolls were technically of a particular style.

The process of mummification in the late period mostly concentrated on the outside coverings rather than treating the body internally. Wrapping linen as well as some linen in the form of linen shrouds, some of which are still at the site, were discovered there. Due to the physical and chemical reaction between the linen shrouds and the mummification ingredients employed on the mummy's surface, many of these linen shrouds unfortunately suffer from extreme fragility (15).

The mummy's body decayed due to flaws in the mummification procedure and materials used, leaving no skeletal remnants. There were several linen rolls discovered, but many of them were in poor condition due to chemical degradation caused by mummification materials interacting with the wrapping linen. As a result, the components of the wrappings disintegrated.

Since the pre-dynastic period, the ancient Egyptians had perfected the art of spinning and weaving. This is evidenced by the presence of looms and spindles in Middle Kingdom tombs. The recreated weaving factory in the Meketre tomb is very impressive (16). The tomb imagery provides a vivid depiction of the spinning and weaving industry in ancient Egypt.

Linen fabric wrappings were an essential aspect of the ancient Egyptian burial procedure, and their use persisted throughout the Late Period. The Late Period in Egyptian history lasted from 664 to 332 BCE and was marked by political instability and foreign influence. Despite these developments, traditional beliefs and practices concerning the burial of the dead have remained largely untouched, Linen was regarded as a sacred cloth in ancient Egypt, and its usage in wrapping mummies was thought to protect the deceased's body and aid them in their trip to the afterlife. Linen was employed in mummification as early as the Old Kingdom (2686-2181 BCE) and remained popular until the end of the pharaonic dynasty in 332 BCE (17).

The mummification procedure included multiple processes, including the removal of internal organs, drying out the body, and wrapping the body in linen. The wrappings were designed to preserve and protect the body from decay, as well as to ensure that the departed might be identified in the afterlife, Mummy wrappings became more ornate throughout the Late Period than in previous periods. Typically, the mummy was covered in layers of bandages, each meticulously placed and smoothed over. The bandages were frequently embroidered with complex designs and hieroglyphs to aid the deceased on their trip to the afterlife (18).

The use of hieroglyphs in bandage ornamentation was especially important during the Late Period, when it was believed that the written word possessed magical power. The hieroglyphs were intended to provide instructions for navigating the afterlife and safeguarding those who died from threats (19).

The mummy was frequently enclosed in a wooden coffin that was also decorated with intricate carvings and inscriptions in addition to linen bandages. The larger sarcophagus, which was likewise adorned with hieroglyphs and pictures of gods and goddesses, was frequently used to house the coffin. (20)

It was thought that the images and inscriptions on the coffins and sarcophagi would offer the departed protection and support in the afterlife, therefore the decoration of the coffins and sarcophagi during the Late Period was extremely complex. Egyptian mythological scenarios, such as the ceremony of weighing the heart, which was thought to determine whether or not the deceased would be permitted to reach the afterlife, were frequently shown in the paintings and inscriptions (21).

2. Materials and methods

2.1 Samples

The mission found several mummies covered in shrouds during the season, which can be sorted into four categories:

I. The body was wrapped in a shroud and tied to the surface with two strips, 1.7 cm wide, crossing diagonally on the chest. The external layer consisted of horizontal wrappings, 1.5 cm wide, binding the entire body from head to feet, with the feet being wrapped with wider strips that were more tightly spaced than on the rest of the body. (fig.3)

II. The body was wrapped in a shroud and tied with thin intersecting strips of bandages (1.3 cm wide) to form a rhomboid net pattern on the surface.

III. The bodies were wrapped in shrouds and tied diagonally on the surfaces with wider strips of bandages (5 cm wide), with the tying being horizontal.

IV. The external layer was formed of 12 strips of bandages of equal width, looped horizontally around the body from head to knees. A number of mummies had two strips, 1.5 cm wide, crossing diagonally on the pelvis and knees.

In addition, some damaged burials were found consisting of loose bones in fragmentary condition mixed with scraps of bandages. The bones, especially in the facial part of the skull, were crushed under the pressure of sand, limestone pebbles, and cobbles covering the bodies. Samples were obtained through Misr University for Science and Technology, Faculty of Archaeology and Tourism Guidance, site in Saqqara and through burial shafts 8, 9 and 10, as shown in (figures. 2,4).

Fig. 3 points at one of the mummies that was discovered at the Taba El-Geish site in Saqqara, the linen fiber wrappings of the mummy were analyzed as a part of this research.

Fig. 4 points at the samples that underwent various types of research examination and analysis in the present study. Photography by the Researcher

2.2 Visual Examination

To determine the relative density of the shrouds, a thread count was conducted in various areas. A counting glass is used to determine the thread count. To count or measure the total number of strands in both the warp and weft directions, counting glasses with a one-centimeter square shape produced from magnifying glasses are useful objects (22).

The average results showed 37, 24, 15, 35 warps and 18, 12, 15, 17 wefts per centimeter, with typical variations in yarn counts on the same cloth due to normal irregularities in the weave and associated deterioration of looted archaeological artifacts (23). (Tab.1).

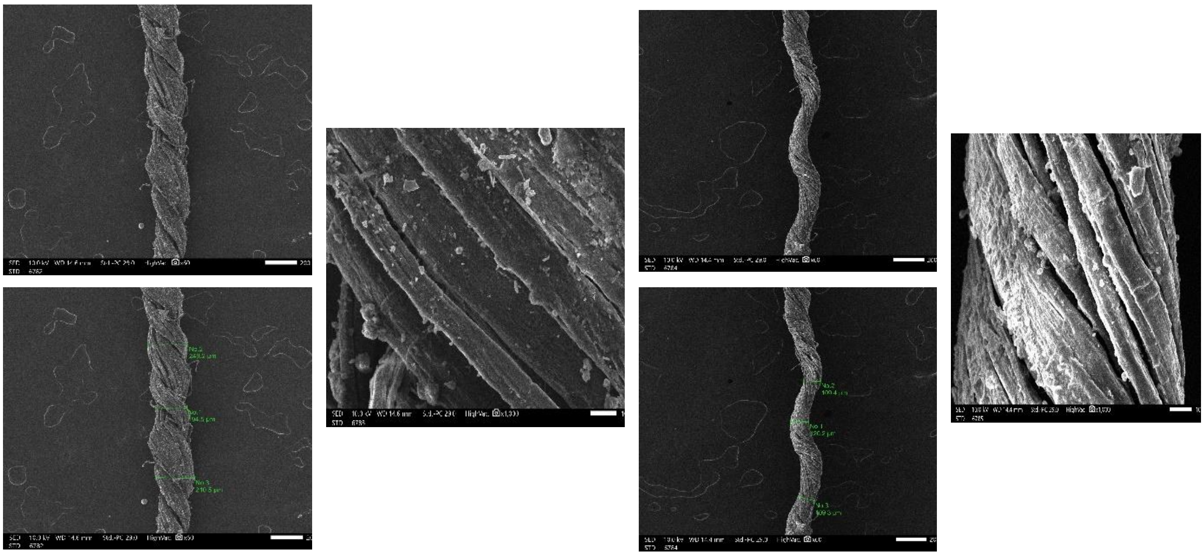
TABLE 1 calculate the relative density of shrouds

Object	Weaving Structures	Fabric density (threads/cm)		Fiber identification	
		Warp	Weft	Warp	**Weft**
Shroud A	Plain weave1/1	37	18	Linen	**Linen**
Shroud B	Plain weave1/1	24	12	Linen	**Linen**
Shroud C	Plain weave1/1	15	15	Linen	**Linen**
Shroud D	Plain weave1/1	35	17	Linen	**Linen**

2.3 Scanning Electron Microscope (SEM)

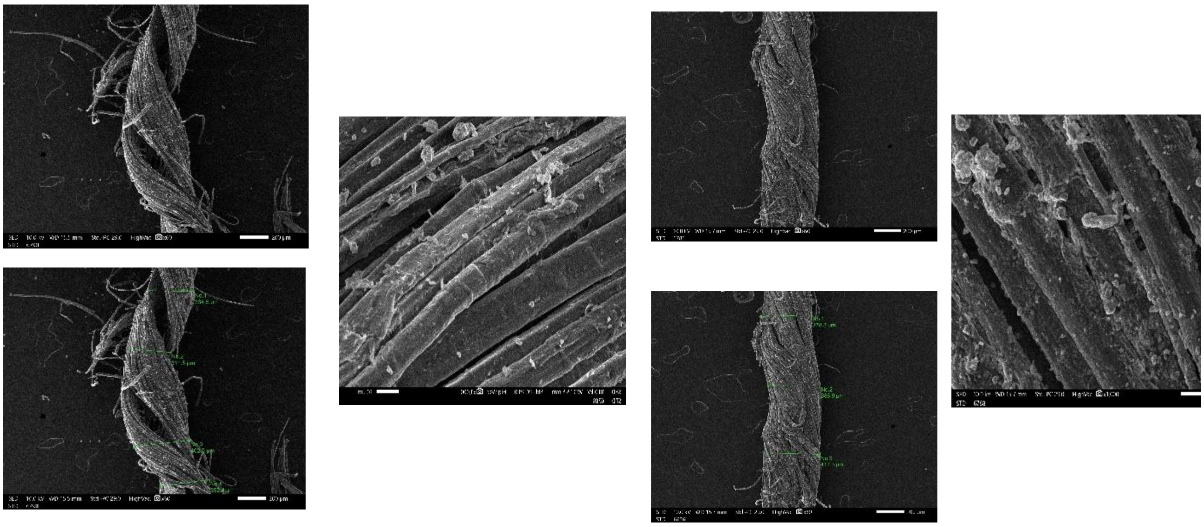
SEM-JEOL (JFC-1100E Ion Sputtering Apparatus, Model JSM-5300, JEOL Co., Tokyo, Japan) was used in the central laboratory of the Faculty of Science at Alexandria University to study the warp and weft fibers of selected samples. A sample of a few millimeters was taken, and several magnifications were used. A thin layer of gold was applied to the yarn samples using an Edwards Scan Coat Six device for 180 seconds after they had been bonded to a sample holder using conductive adhesive (24).

Examination (25) via SEM revealed that both the warp and weft threads were made of flax fibers, which are distinguished by the presence of swollen nodes and joints along the longitudinal view of the fiber, shown in figures. 5, 6, 7, and 8. (Tab. 2)



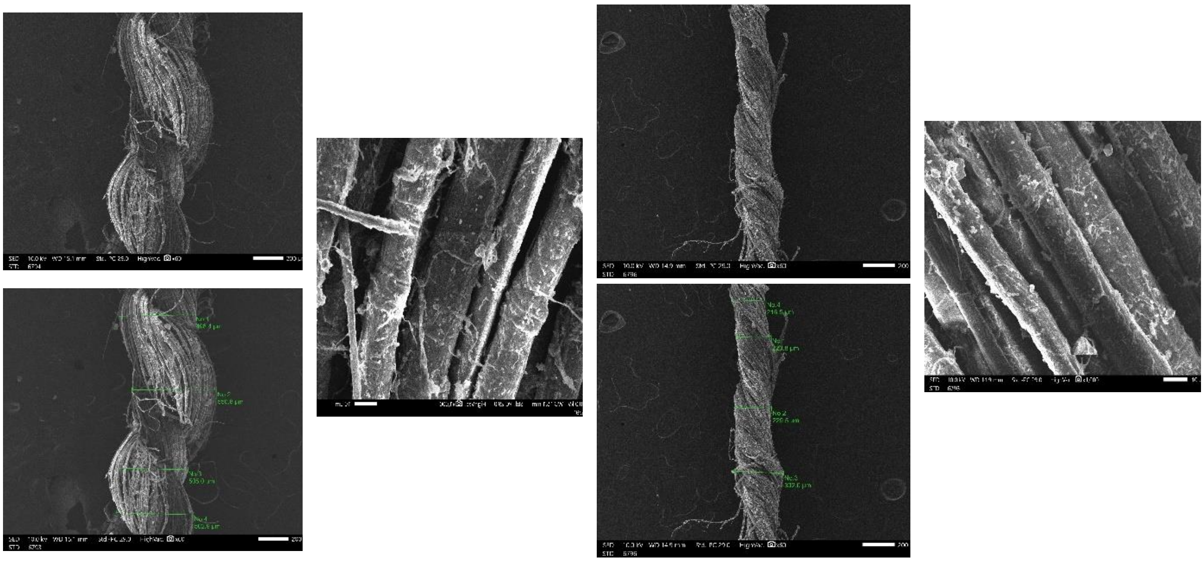
Spinning direction of two-ply warp yarn. **Flax fibers of warp** **Spinning direction of single weft yarn.** **Flax fibers of weft**

Fig. 5. Scanning electron microscope investigation of warp and weft thread of shroud No. A.



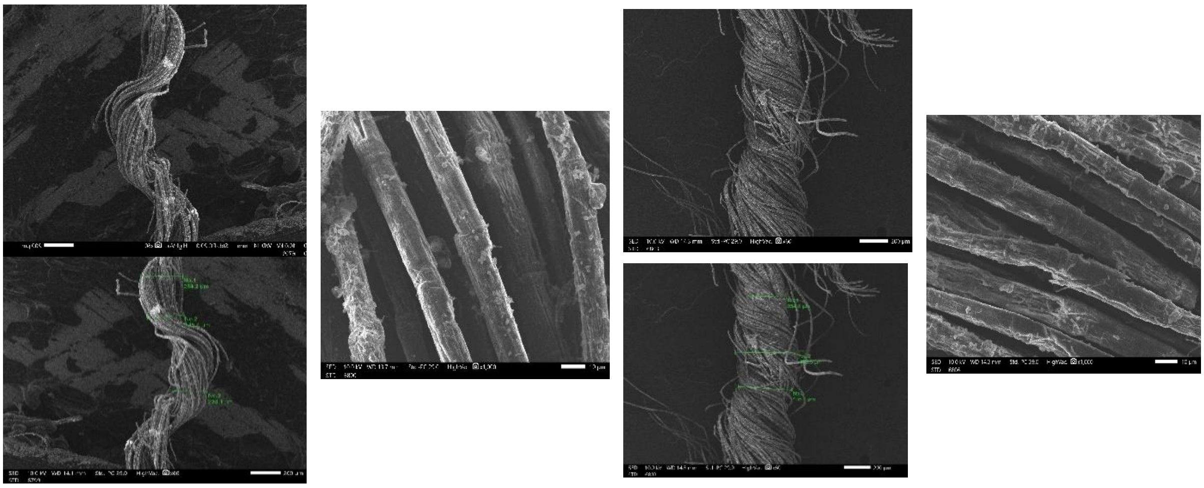
Spinning direction of two-ply warp yarn. **Flax fibers of warp** **Spinning direction of single weft yarn.** **Flax fibers of weft**

Fig. 6. Scanning electron microscope investigation of warp and weft thread of the shroud No. B



Spinning direction of two-ply warp yarn. **Flax fibers of warp yarn.** **Spinning direction of single weft yarn.** **Flax fibers of weft yarn.**

Fig. 7. Scanning electron microscope investigation of warp and weft thread of shroud No. C



Spinning direction of two-ply warp yarn. **Flax fibers of warp** **Spinning direction of weft thread** **Flax fibers of weft**

Fig. 8. Scanning electron microscope investigation of warp and weft thread of shroud No. D

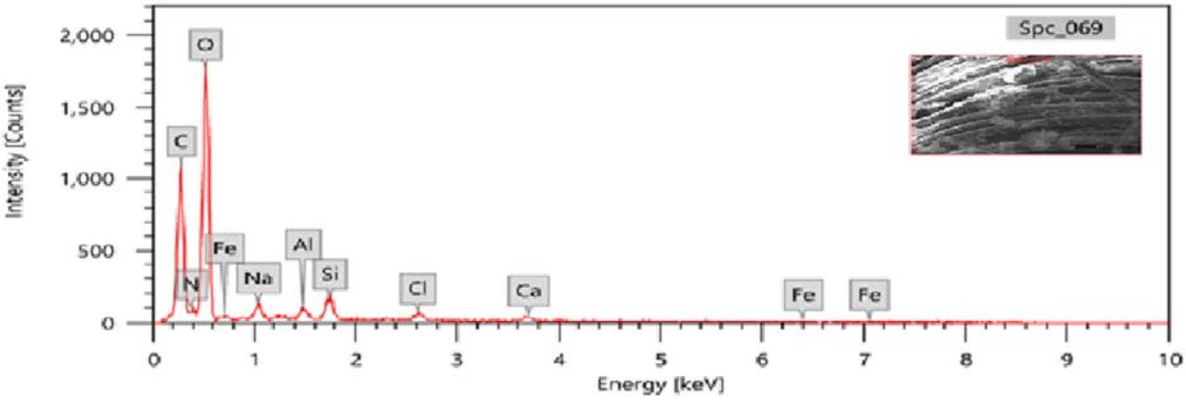


Fig. 9a: SEM-EDX (X 1.600) pattern of red dye mordant which indicate the presence of aluminum.

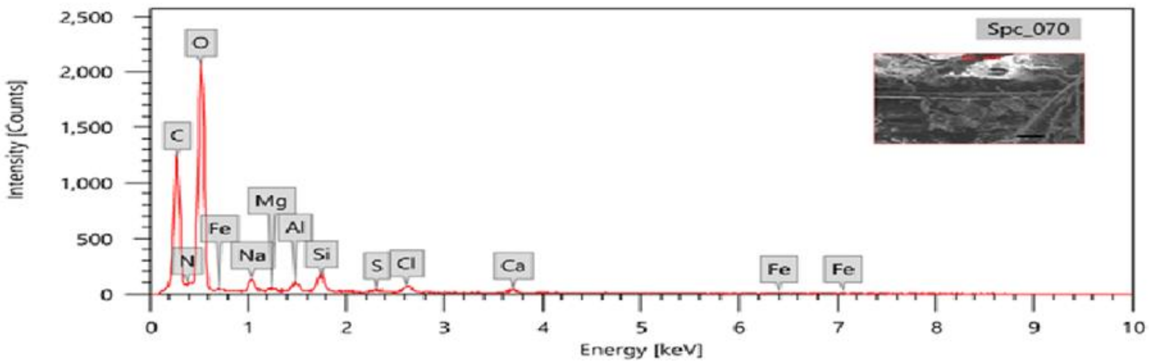


Fig. 9b: SEM-EDX (X 550) pattern of red dye.

Table 2. EDAX data of the studied mordant dye

Sample element	C	N	O	Na	Mg	Si	S	Cl	Ca	Fe
%	33.55	1.38	52.44	2.21	---	1.60	3.42	---	2.39	2.59
	33.69	1.83	52.24	2.07	0.46	1.36	2.92	0.50	2.38	1.95

2.4 Gas Chromatography –Mass Spectrometry (GC-MS) analysis

Using a Thermo Scientific GC-TSQ mass spectrometer and a direct capillary column TG-5MS (30 m x 0.25 mm x 0.25 m film thickness), the chemical composition of the samples was determined. (Thermo Scientific, Austin, TX, USA). The column oven's temperature was first maintained at 60°C, increased by 5°C/min to 250°C with a delay of 2 minutes, and then increased to 300°C by 30 C/min. The injector's temperature was maintained at 270°C. One milliliter of helium was employed as a carrier gas at a steady pace. Using an Autosampler AS3000 and GC in split mode, diluted samples of 1 l were automatically injected with a solvent delay of 4 min. m/z 50–650 EI mass spectra were gathered in full scan mode at 70 eV ionization voltages. The ion source and transfer line were both adjusted to temperatures of 200 °C and 280 °C, respectively. By comparing the mass spectra of the components to those in the mass spectral databases WILEY 09 and NIST 14, the components were identified (26).

The chemical constituents of the dye were identified by comparing their mass spectra with those in the WILEY 09 and NIST14 mass spectral databases {26}. The GC-MS chromatogram is presented in Figure 10, and the names of the active compounds along with their retention times (RT) and base peaks are presented in Table 2. The spectra of the compounds are shown in Fig.10a-h. (Table. 3) (28).

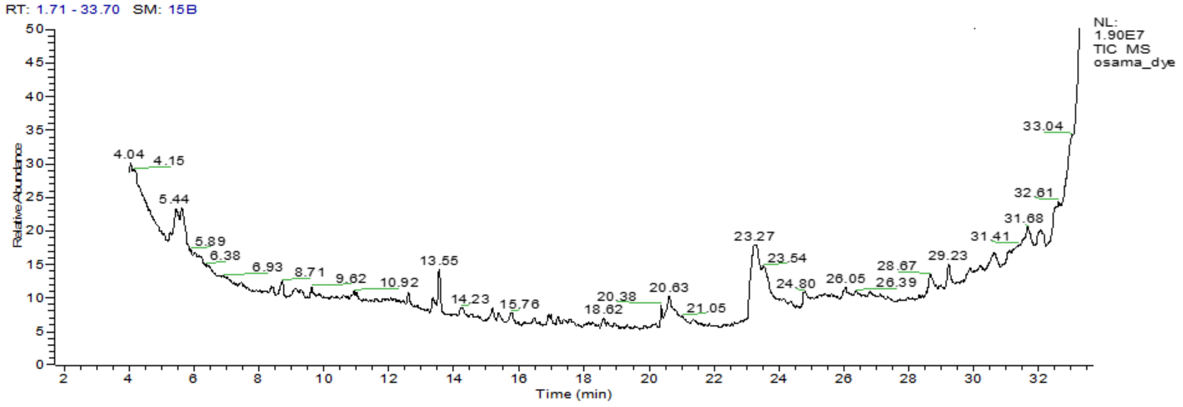


FIG.10. the GCMS chromatogram of the red dye.

Table 3. The most important compounds of GCMS chromatogram of the red dye with their retention time (RT).

Peak report			
ID	**RT**	**Name of compound**	**Molecular weight**
1	4.16	9,12,15-OCTADECATRIENOIC ACID	440
2	12.59	9,12-OCTADECANOIC ACID (Z, Z)-	498
3	17.99	9-OCTADECENOIC ACID(Z)-	280
4	21.63	HEXADECADIENOIC ACID, METHYL ESTER	266
5	22.63	OLEIC ACID	282
6	24.39	HI-OLEIC SAFFLOWER OIL	450
7	24.56	OXIRANEOCTANOIC ACID,3-OCTYL-, CIS-	298
8	31.35	PALMITIC ACID, 2-(TETRADECYLOXY)ETHYL ESTER	496

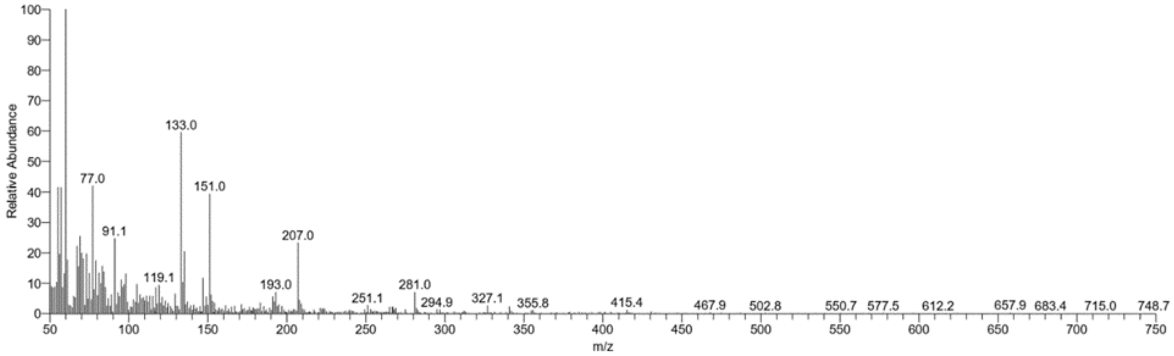


Fig. 10a shows the mass spectrum of 9,12,15-octadecatrienoic acid.

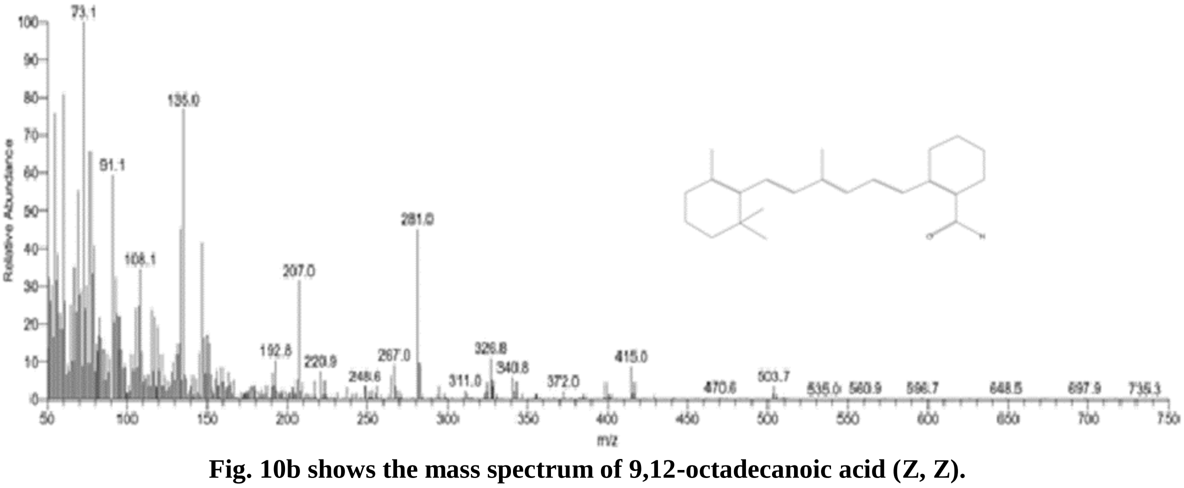


Fig. 10b shows the mass spectrum of 9,12-octadecanoic acid (Z, Z).

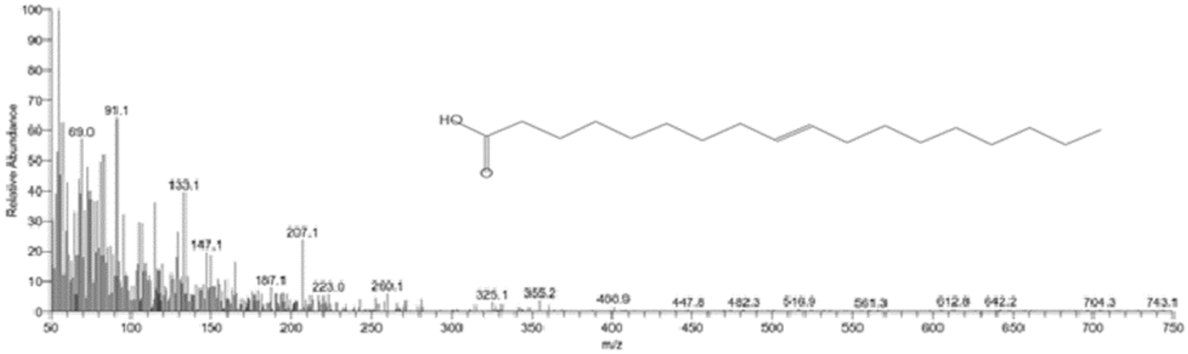


Fig. 10c shows the mass spectrum of 9-octadecenoic acid (Z).

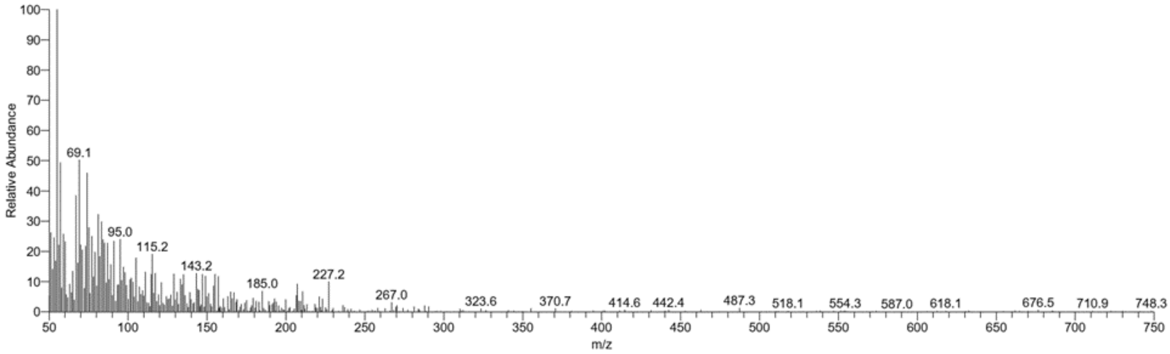


Fig.10d shows the mass spectrum of methyl hexadecadienoate.

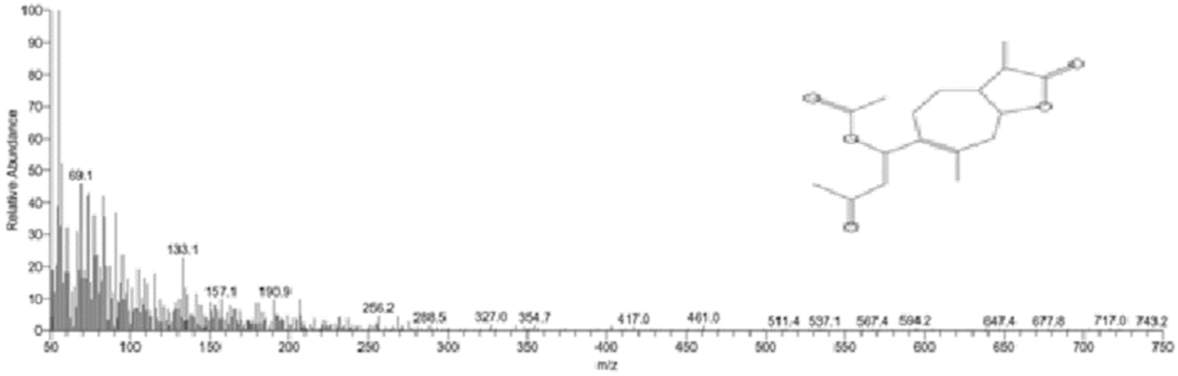


Fig. 10e shows the mass spectrum of oleic acid.

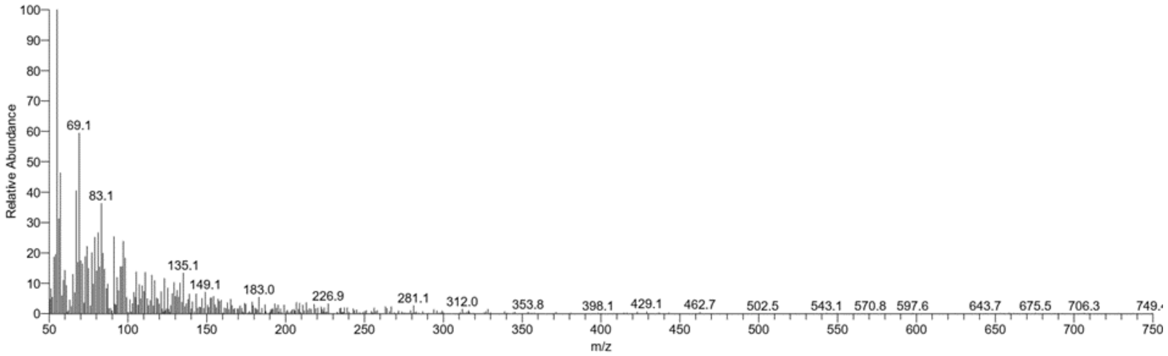


Fig. 10f shows the mass spectrum of high-oleic safflower oil.

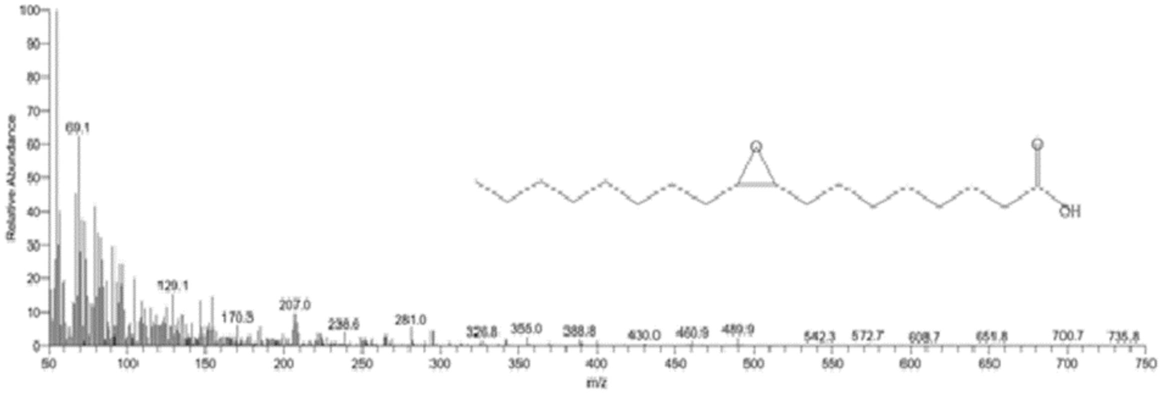


Fig. 10g shows the mass spectrum of cis-3-octyl-oxirane octanoic acid.

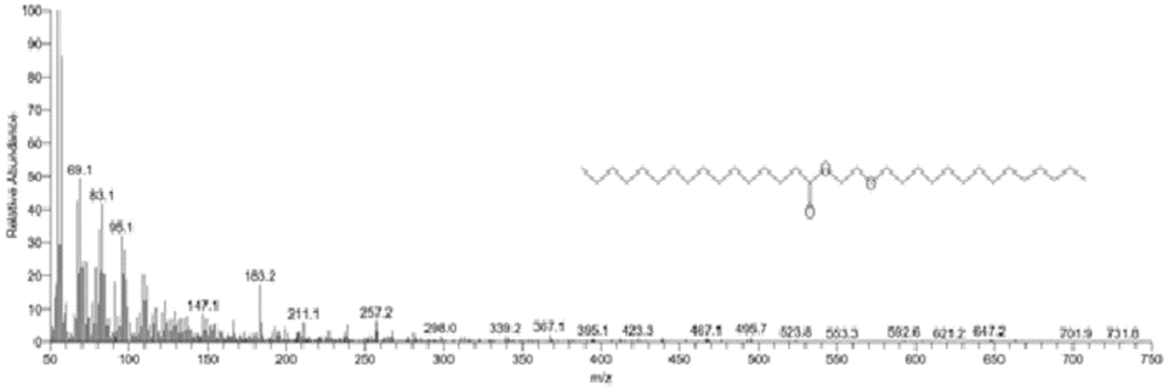


Fig. 10h shows the mass spectrum of 2-(tetradecyloxy)ethyl palmitate.

3. Results and discussion:

I. The weaver took great care to ensure that the warp threads on the loom were plied threads, which distinguished the formation of the weaving shed from the longitude of the warp threads and shaped the essence of the stressed weaving warp. This indicates that the weaver was experienced and understood the stresses of the loom movement on the warp threads (fig.5-8) (29). This understanding began with the weavers of pre-dynastic times. Midgley's examination of 22 fabrics recovered from three mastabas in this necropolis from the pre-dynastic period revealed that 17 of these samples included plied warp threads (30).

II. All of the threads examined had plied yarns in the S2 form, which was a distinctive characteristic of ancient Egyptian fabric. (fig.5-8) (31).

III. Both the warp and weft are s-twist flax, and the diameter of the single yarns (wefts) varies between 0.12 mm and 0.42 mm, while the diameter of plied yarns (warps) varies between 0.22 mm and 0.51 mm. (fig.5-8)

IV. Through examination, it was determined that the weave structure was plain weave 1/1, which is the most commonly used and simplest structure. Both warp and weft threads follow a sequence of over one and under one, which is known as plain weave (or tabby). (fig.5-8) (32)

V. One of the linen shrouds showed evidence of safflower dye “No. C”, which was commonly used by ancient Egyptians to dye linen. (fig.10&table3) {32}. From the previous compounds it is clear that from comparing it with the literature, the compounds 9,12-OCTADECANOIC ACID (Z, Z)-, HEXADECADIENOIC ACID, METHYL ESTER and 9-OCTADECENOIC

ACID(Z)-, are found in Safflower seeds. Through the compounds that appeared in the analysis, it is clear that the dye present is safflower dye (34).

VI. SEM-EDS mordant analysis of the safflower-dyed shroud confirmed the presence of elements such as C, N, O, Na, Mg, Al, Si, S, Cl, Ca, and Fe. These findings coincide with the research regarding the presence of the same elements. (fig.9a,9b&table.2) (35).

V. Conclusion:

This conclusion summarizes the key findings of the scientific paper on the linen industry in ancient Egypt. The study used scientific methods to evaluate the quality of flax used in the industry and the dyeing process, with a focus on mordant dyeing of safflower with an aluminum mordant.

The study focused on evaluating the quality of flax used in the linen industry in ancient Egypt, particularly during the later period at the archaeological Saqqara site. The researchers utilized scientific methods to examine the chemical composition of the flax and the dyeing process, specifically mordant dyeing of safflower with an aluminum mordant.

The research findings suggest that the quality of flax used in the industry was weak in terms of its chemical composition, which could have affected the durability and overall quality of the linen products.

Overall, the study provides valuable insights into the ancient Egyptian linen industry and sheds light on the factors that may have influenced the quality and longevity of their linen products.

VI. Acknowledgment

The researchers would like to express their gratitude to the archaeological mission of MUST University in collaboration with the Supreme Council of Antiquities operating in Saqqara for providing them with the opportunity to obtain samples and examine them on site. The lead researcher is also a member and responsible for the restoration of the mission.

References

1.Zahi, H., Hawass, Z., Abdelrahman, M., & Ismail, S. (2021). Excavations at the Saqqara Necropolis: A New Old Kingdom Discovery. Near Eastern Archaeology, 84(2), 78-85. https://doi.org/10.5615/neareastarch.84.2.

2.Ikram, S., & Dodson, A. (2008). The Tomb in Ancient Egypt: Royal and Private Sepulchers from the Early Dynastic Period to the Romans. Thames & Hudson.

3.Waddell, L. A. (1921). The Linen Industry in Ancient Egypt. The Journal of Egyptian Archaeology, 7(3/4), 180-184.

4.Berlin, A. M. (2001). Linen in Ancient Egypt. Archaeology, 54(1), 46-51.

5.Johnstone, J. (2007). The Egyptian Linen Industry in the Roman World. Bulletin of the American Society of Papyrologists, 44, 31-47.

6.Oleson, J. P. (1973). Textiles in Ancient Egypt. Technology and Culture, 14(4), 462-479.

7.Waddell, L. A. (1921). The Linen Industry in Ancient Egypt. The Journal of Egyptian Archaeology, 7, 243-249.

8.Johnstone, J. (2007). The Egyptian Linen Industry in the Roman World. Bulletin of the American Society of Papyrologists, 44, 34-46.

9.Berlin, A. M. (2001). Linen in Ancient Egypt. Archaeology, 54(1), 87-92.
10. Oleson, J. P. (1973). Textiles in Ancient Egypt. Technology and Culture, 14(4), 423-430.
11. Bourriau, J. (1999). The Late Period. In I. Shaw (Ed.), The Oxford History of Ancient Egypt (pp. 369-394). Oxford University Press.
12. Ikram, S., & Dodson, A. (1998). The Mummy in Ancient Egypt: Equipping the Dead for Eternity. Thames & Hudson.
13. Taylor, J. H. (2001). Death and the Afterlife in Ancient Egypt. University of Chicago Press.
14. Nunn, J. F. (1996). Ancient Egyptian Medicine. University of Oklahoma Press.
15. Pinch, G. (2018). Egyptian Mythology: A Guide to the Gods, Goddesses, and Traditions of Ancient Egypt. Oxford University Press.
16. Nicholson, P. T., & Shaw, I. (2000). Ancient Egyptian Materials and Technology. Cambridge University Press, 189-196.
17. Ikram, S. (1995). Choice Cuts: Meat Production in Ancient Egypt. Journal of the American Research Center in Egypt, 32, 111-134.
18. Ritner, R. K. (2015). The Mechanics of Ancient Egyptian Magical Practice. The Journal of the American Oriental Society, 135(4), 635-654.
19. Ikram, S., & Dodson, A. (1998). The Mummy in Ancient Egypt: Equipping the Dead for Eternity. Thames & Hudson, 347-351.
20. Taylor, J. H. (2010). Coffins of the Third Intermediate Period. Metropolitan Museum Journal, 45, 69-88.
21. Nicholson, P. T., & Shaw, I. (2000). Ancient Egyptian Materials and Technology. Cambridge University Press, 195-201.
22. Islam, S., Chowdhury, S., & Akter, S. (2018). The Experiential Analysis of Woven Fabric for Reproduction. Journal of Textile Science and Technology, 4, 18-48.
23. Murphy, D. B. (2001). Fundamentals of Light Microscopy and Electronic Imaging. Wiley, 35-41.
24. "SEM SUPPLIES" Science Services. (2016). Germany.
25. Goldstein, J., Newbury, D. E., Michael, J. R., Ritchie, N. W. M., Scott, J. H. J., & Joy, D. C. (2018). Scanning Electron Microscopy and X-Ray Microanalysis. Springer, 91-98.
26. Abd El-Kareem, M. S. M., Rabbih, M. A., Selim, E. T. M., & Elsherbiny, E. A. (2016). Application of GC/EIMS in Combination with Semi-Empirical Calculations for Identification and Investigation of Some Volatile Components in Basil Essential Oil. International Journal of Analytical Mass Spectrometry and Chromatography, 4, 14-25.
27. Wang, Y., Yang, F., Gritsenko, M. A., Clauss, T. R. W., Liu, T., Shen, Y., ... & Smith, R. D. (2016). Recent advances in sample preparation techniques for mass spectrometry analysis. Analyst, 141(2), 636-655.
28. Watson, J. T., Sparkman, O. D., & Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation. (2007). John Wiley & Sons, 423-430.
29. Rahnev, I. (2019). Warp Threads Stress Variation during Handloom Weaving. AUTEX2019-19th World Textile Conference on Textiles at the Crossroads, 11-15 June 2019, Ghent, Belgium, 4.
30. Lucchesi, C. S. (2018). The Unwound Yarn Birth and Development of Textile Tools Between Levant and Egypt. Edizioni Ca’Foscari, Venezia, 76.

31. Barry, J. K., & Eastwood, G. V. (2001). The Ancient Textile Industry at Amarna. Egypt Exploration Society, 5-12.

32. Hann, M. A., & Thomas, B. G. (2005). Patterns of Culture Decorative Weaving Techniques. Ars Textrina, 36, 8.

33. Abdel-Kareem, O. (2012). History of Dyes used in Different Historical Periods of Egypt. Research Journal of Textile and Apparel, November 2012, 87.

34. Hagar, T. E., Adam, I. A., Mohammed, E. H., & Abd El Mageed, M. (2021). GC/MS Analysis and Antioxidant Activity of Fixed Oil from Sudanese Safflower (Carthamus tinctorius L) Seeds. International Journal of Advanced Biological and Biomedical Research, 9(2), 138-146.

35. Tamburini, D., Dyer, J., Davit, P., Aceto, M., Turina, V., Borla, M., ... & Gulmini, M. (2019). Compositional and Micro-Morphological Characterization of Red Colorants in Archaeological Textiles from Pharaonic Egypt. Molecules, 24, 3761, 5-11.